AI and Machine Learning for Treatment Planning and Image Segmentation

Carlos E. Cardenas, PhD

Disclosures

• Varian Medical Systems
• NIH
• MD Anderson Cancer Center
• MD Anderson Internal Research Grant

Key Points

• Why automated contouring and treatment planning are essential in our quest to improve radiotherapy
• Brief overview of AI for medical imaging
• AI-based auto-segmentation
  • Normal tissues
  • Target volumes
• Automated treatment planning
Why Automated Treatment Planning

Staff Shortage Worldwide

![Chart showing staff shortage](chart.jpg)

**Teletherapy units**
- Existing: 5,000
- Presently required: 12,000
- Required by 2020: 25,000
+220%

**Radiation Oncologists**
- Existing: 1,000
- Presently required: 2,100
- Required by 2020: 4,000
+103%

**Medical Physicists**
- Existing: 2,000
- Presently required: 4,000
- Required by 2020: 6,000
+292%

**Radiotherapy technologists**
- Existing: 5,000
- Presently required: 6,000
- Required by 2020: 8,000
+270%

Figure from: Kelly Kisling, PhD

Why Automated Treatment Planning

- Time consuming task
- Involves a team of highly trained staff
- Several hand-offs
- From simulation CT to plan approval ~ 5 work days

Why Automated Treatment Planning

Humans are “humans”

- “We are quite bad at making complex unaided decisions”
  - (Slovic, P; Fischhoff, B; and Lichtenstein, S. Annual Review of Psychology. 1977, 28:1, 1-39)
- As humans (professionals) we use our intuition, training, and experience to identify the “best” solution

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Why Automated Treatment Planning

Humans are “humans”

We are not “perfect”

Different Interpretations/Ideas

Automation in Radiation Oncology

• Automation as Decision Support Systems
  • Not here to replace us, but to augment our knowledge
  • Staff shortages
  • Low- and middle-income countries
• Reduce costs and improve clinical workflows
• Reduce uncertainties in radiotherapy
Introducing Artificial Intelligence

What is AI?

• Artificial intelligence is a subfield in computer science that focuses on the development of intelligent agents that mimic cognitive functions such as learning and problem solving.
• The goal of an artificial intelligence system is to perceive a problem and take an action that maximizes the likelihood of successfully achieving a desired goal.

Figure 1. Illustration showing the relationship between artificial intelligence, machine learning, and deep learning.

Machine Learning

• Machine learning or statistical learning, is a subfield of artificial intelligence where mathematical algorithms are able to learn patterns from data which can then be used to make informed decisions when presented with new observations.
Examples: LASSO, random forests, artificial neural networks, etc.

Figure 1. Illustration showing the relationship between artificial intelligence, machine learning, and deep learning.
Deep Learning

- Deep learning is a subfield of machine learning which focuses on the use of deep neural networks which were traditionally defined as artificial neural networks that have more than 2 "hidden" layers between the input and output layers; however, with today's computational power, deep neural networks can have hundreds of hidden layers.

Figure 1. Illustration showing the relationship between artificial intelligence, machine learning, and deep learning.

Machine Learning vs Deep Learning

- When compared with traditional machine learning approaches, deep learning provides the advantage that the previously user-defined features are now "learned" and defined by the deep learning algorithm based on the input data used to train the model.
- This allows for more robust generalization of the model on unseen data (not used during training).

Human Interaction
Convolutional Neural Networks

- Widely used in medical imaging analysis due to their ability to provide local connectivity between neurons of adjacent layers exploiting spatially local correlations.

Images from http://cs231n.github.io/convolutional-networks/

Al-based auto-segmentation
A lot of history with non AI-based approaches

- Clinical deployment (2016) at MD Anderson of our in-house atlas-based auto-segmentation algorithm for head and neck normal tissues.
- Initial evaluation of the algorithm
• Clinical deployment (2016) at MD Anderson of our in-house atlas-based auto-segmentation algorithm for head and neck normal tissues.
• Initial evaluation of the algorithm
• Retrospective analysis of 1st 128 consecutive cases treated using these contours and compared the clinical contours (edited if needed) and auto-segmentation
• 50% of contours didn’t require edits
• Atlas-based clinically acceptable for the majority of cases

Carlos E. Cardenas, PhD
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Deep Learning Boom

Medical image auto-segmentation publications in the past 2 decades


U-Net: Convolutional Networks for Biomedical Image Segmentation

V-Net: Fully Convolutional Neural Networks for Volumetric Medical Image Segmentation
Figure 2: The base network architecture is shown for DAB-CNN. The ICs selectively propagate information from the encoding stage to the decoding stage, allowing for more efficient utilization of network parameters.
Automation in Treatment Planning

Support Vector Machine

Zhao MED PHYS 2012
Radiation Planning Assistant

- Auto 3D isodose generation
- Auto 3D isodose regions
- Determination of field arrangement
- Dose optimization

Coming Soon!

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